

USAFSAM-TP-87-2

AD-A205 864

THE USE OF ARTIFICIAL INTELLIGENCE FOR THE IDENTIFICATION OF BACTERIA

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January 1989

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Final Report for Period December 1985 - March 1988

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USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0183

1a REPORT SECURITY CLASSIFICATION Unclassified		1b RESTRICTIVE MARKINGS	
2a SECURITY CLASSIFICATION AUTHORITY		3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.	
2b DECLASSIFICATION / DOWNGRADING SCHEDULE		4 PERFORMING ORGANIZATION REPORT NUMBER(S) USAFSAM-TP-87-2	
5 MONITORING ORGANIZATION REPORT NUMBER(S)		6a NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine	
6b OFFICE SYMBOL (if applicable) USAFSAM/EKLM		7a NAME OF MONITORING ORGANIZATION	
6c ADDRESS (City, State, and ZIP Code) Human Systems Division (AFSC) Brooks AFB, TX 78235-5301		7b ADDRESS (City, State, and ZIP Code)	
8a NAME OF FUNDING / SPONSORING ORGANIZATION USAF School of Aerospace Medicine		8b OFFICE SYMBOL (if applicable) USAFSAM/EKLM	
9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		10 SOURCE OF FUNDING NUMBERS	
10a ADDRESS (City, State, and ZIP Code) Human Systems Division (AFSC) Brooks AFB, TX 78235-5301		PROGRAM ELEMENT NO 87714F	PROJECT NO SUPT
		TASK NO XX	WORK UNIT ACCESSION NO EK
11 TITLE (Include Security Classification) The Use of Artificial Intelligence for the Identification of Bacteria			
12 PERSONAL AUTHOR(S) McCleskey, Ferne K.; Cosgrove, Donald J.; Hartman, Fred W.; and Thomas, Janelle			
13a TYPE OF REPORT Final	13b TIME COVERED FROM 85/12 TO 88/03	14 DATE OF REPORT (Year, Month, Day) 1989, January	15 PAGE COUNT 18
16 SUPPLEMENTARY NOTATION			
17 COSATI CODES		18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
06	13		
12	09		
19 ABSTRACT (Continue on reverse if necessary and identify by block number) A method has been investigated to provide more rapid and more efficient identification of bacteria using artificial intelligence, a process in which a computer can examine a variety of facts and devise a solution by comparing the facts with a data base. Incorporated into the data base are the names of 564 species of medically important bacteria with 0-90% positive or negative results of biochemical reactions for the identification of each species. In a rapid search of the data base, the computer selects the three most likely organisms with a likelihood index for each. This application of artificial intelligence eliminates tedious matching with biochemical charts; it can be used by the less skilled technician.			
20 DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED / LIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21 ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a NAME OF RESPONSIBLE INDIVIDUAL Ferne K. McCleskey		22b TELEPHONE (Include Area Code) (512) 536-3381	22c OFFICE SYMBOL USAFSAM/EKLM

THE USE OF ARTIFICIAL INTELLIGENCE FOR THE IDENTIFICATION OF BACTERIA

INTRODUCTION

In the early and mid-1960's a number of investigators working independently began a search for a way to use existing mathematical models to formulate biochemical data bases for bacterial identification (1,2,3,4). These programs are mathematical manipulations of a data base matrix utilizing some form of Bayesian probability. Bacterial identification through computer manipulation of a large data base could be performed faster and more accurately than most microbiologists could achieve with identification charts (4,5). Manufacturers of commercial kits and automated and semi-automated equipment have effectively used these procedures to identify the more commonly isolated organisms.

METHODS AND MATERIALS

In 1985 a cooperative study was undertaken by the Epidemiology Division and the Data Services Branch, Technical Services Division, USAF School of Aerospace Medicine, Brooks Air Force Base, Texas to determine the possibility of using artificial intelligence for bacterial identification. The bacterial identification system uses conventional biochemical tests with daily readings, for periods ranging from 2 to 7 days (Fig. 1).

The protocols for testing are taken from published data of the Centers for Disease Control, American Type Culture Collection and Manual of Clinical Microbiology, 4th edition. Definitive identification of genus, species, and biotype is achieved through the comparison to charts representing large numbers of organisms which have been tested with each biochemical test, providing a percentage positive and a percentage negative reaction for each test (Fig. 2).

The data base consists of genus and species names of 564 organisms with biotypes as appropriate; all possible biochemical reactions 0-90% positive or negative; flags to alert the microbiologist to unusual or serious pathogens; recommendations for further tests; and probability percentages for closely related organisms.

At this point every test result obtained on the unknown is compared against every organism in that particular group. No expert knowledge about individual test results versus particular organisms is applied at this point. Every test has equal weight. This is a Bayesian-like procedure, but since the original population of the unknown is not known, the a priori probabilities of occurrence of particular organisms is unknown. Therefore, the numbers obtained to rank each organism are not probabilities but likelihoods. These likelihoods are ranked, thus reducing the search space to the top three most likely candidates.

The expert system has now reached the goal state, but with three candidates. Since the goal has been reached without using any rules to exclude particular organisms, the program now backward chains from those candidates to advise the microbiologist of any inconsistencies between the test results and the three candidates under consideration. Subroutines have been coded for each family group which contain expert knowledge about individual organisms.

These rules are then applied to the three candidates. Another subroutine, which is optional, can search the data base on its own and advise the human expert on situations which are highly unlikely.

After these rules are applied, the decision of the most likely candidate is left to the microbiologist (Fig. 3).

Gram's stain results and cultural characteristics dictate the specific protocol for testing. There are 15 specific biochemical protocols or lists used: List #1=Enterobacteriaceae; List #2=Vibrionaceae; List #3=Capneic gram-negative bacilli and coccobacilli; List #4=gram-negative nonfermenting bacilli; List #5=Hemophilus species; List #6=Fastidious gram-negative rods and coccobacilli; List #7=Streptococcus species; List #8=Corynebacterium species, and related gram-positive bacilli; List #9=gram-negative cocci; List #10=Anaerobes; List #11=Staphylococcus species; List #12=Listeria species and Erysipelothrix; List #13=Lactobacillus species; List #14=Bacillus species; and List #15=Unusual gram-negative bacilli such as Simon-siella and Erwinia. These lists can be shown on the computer format by requesting the identification program 5 or 11 (Fig. 4).

Artificial intelligence can now provide expert status for bacterial identification. Expert status is defined as the ability of this system to identify isolates as well as, or better than, a microbiologist using charts. The computer printout is much more rapid than visual comparison and presents numerical likelihood of identification for the three most likely organisms.

The biochemical tests performed for each test list are in the appendix. These biochemical tests are available on the computer format when requested from the program menu. The operator enters the results of each test by pressing P for positive, N for negative, and I for test not performed. The results are displayed on the screen with command capability to change erroneous entry prior to the command for data search and display of the bacterial identification. After the three most probable organisms are listed in probability order, the command (continue) can be given to ascertain the positivity index identification (Figs. 5 and 6).

EDITOR'S NOTE: For the convenience of the reader, figures have been placed at the end of the report.

SUMMARY OF CONCLUSIONS

At this time, artificial intelligence has provided a system which identifies isolates as well as, or better than, the microbiologist using extensive charts. The computer identification is much more rapid than visual comparison and identifies the three organisms having the highest confidence levels. The user is also advised of unlikely test reactions and given recommendation for further tests if required.

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NTIS SPA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
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Availability Codes	
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BIOCHEMICAL REACTIONS			
(THIS FORM IS SUBJECT TO THE PRIVACY ACT OF 1974 - USE BLANKET PAS - DD FORM 2005)			
EL NUMBER GRAM STAIN B6-10	DATE 6 Feb 87	NAME Doe, Jane	
Gram negative cocci		BASE	Any place AFB
TCBS AGAR - MACCONKEY AGAR - SS AGAR -		CAMPY AGAR BLOOD AGAR + CHOCOLATE AGAR +	RESULTS Branthamella catarrhalis
Carbohydrate Base	Enteric	O/F Sp	PRB + XV (CTA)
Lactose Neg	HIA:		Spores
Dextrose Neg Gas -	25° C +		Pseudo Agar
Sucrose Neg	37° C +		Hemolysis
Maltose Neg	42° C Neg		Pigment (Blood)
Mannitol Neg	Lysine		Melibiose
Xylose Neg	Ornithine		Hippurate
Glycerol Neg	Arginine		Starch Hyd
O/F Medium (Dex)	Tyrosine Agar Neg		5% Suc Agar
Open Neg	Acetamide		5% Suc Broth
Closed Neg	Tartrate Neg		Veg Hyphae (25@30°C)
Malonate	Acetate Neg		Motility (wet prep)
Urea Neg	Mucate Neg		Serotype No
Motility 25/37° C	Rhamnose		Methyl Red
Gelatin Neg	Arabinose		CDC Blood Agar
Indol R/HIB Neg	Dulcitol		CNA Suppl Agar
Nitrate/Nitrite + / -	Inositol		KVBAP Agar
VP/VP So Neg	Adonitol		BBE Agar
S. Citrate Neg	Salicin		Thayer-Martin Agar
Nut Agar 25/37° C + / +	Trehalose		Yersinia Agar
Oxidase +	Fructose Neg		Anaerobic
Litmus Milk Neg	Sorbitol		CO ₂ Growth Only
Catalase +	Cellulose		Amylase Neg
Centrimide	Raffinose		
Aesculin	Arabitol		
TSI	6% NaCl		
Butt	10% NaCl		
Slant	M B Milk		
H2S (TSI)	ONPG Neg		
Butt	J Tartrate		
Paper +	Phenylalanine +		
Pseudo F	KCN		
Pseudo P	DNase 25/37° C +		
	Lecithinase		
	Lipase		
	TSA (pigment, 25 C)		

AFSC Form 3290, MAR 88 PREVIOUS EDITION WILL BE USED

Figure 1. After an organism's growth characteristics and reactions have been evaluated, the technician records the results on AFSC Form 3290, Biochemical Reactions, for later data entry.

Gram - rods	Pseudomonas stutzeri	Pseudomonas mendocina	Xanthomonas (Pseudomonas) multiphyllia	Pseudomonas diminuta	Pseudomonas putrefaciens biotype 1	Pseudomonas* putrefaciens Biotype 2
O/F	0	0	-	-	-	-
MacConkey	+ 100%	+ 100%	+ 98%	+ 97%	+ 100%	+ 100%
SS	+ 96%	+ 100%	d 43%	- 1%	- 8%	+ 96%
Carbohydrate base	O/F sp.	O/F sp.	O/F sp.	O/F sp.	O/F sp.	O/F sp.
Lactose	- 0%	- 0%	d 60%	- 0%	- 0%	- 0%
Dextrose	A 100%	A 100%	a 90%	d 30%	d 50%	- 0%
Sucrose	- 0%	- 0%	d 64%	- 0%	A 96%	- 0%
Maltose	A 100%	- 0%	A 100%	- 0%	A 92%	- 0%
Rhamnitol	d 89%	- 0%	- 0%	- 0%	- 0%	- 0%
Xylose	A 93%	A 100%	d 36%	- 0%	- 0%	- 0%
Glycerol	d 100%	A 92%	- 1%	- 0%	- 0%	- 0%
Fructose	d 91%	a 100%	d 75%	- 0%	d 66%	- 0%
10% Dex/10% Lact	A/d	A/-	d/-	d/-	d/-	d/-
Urea	d 51%	d 33%	d 28%	d 13%	d 12%	d 42%
Motility 25/35°C	+ 100%	+ 92%	+ 97%	+ 100%	+ 100%	+ 100%
Gelatin hydrolysis	- 1%	- 0%	+ 93%	d 68%	d 65%	+ 100%
Indol	- 0%	- 0%	- 0%	- 0%	- 0%	- 0%
Nitrate/Gas from H03	+ 100/100%	+ 100/100%	d/-	- 3/0%	+ 100/0%	+ 100/0%
Nitrite/Gas from H02	+ 96/96%	d/d 85/85%	- 0/0%	- 0/0%	- 9/0%	+ 100/0%
VP	- 0%	- 0%	- 0%	- 0%	- 0%	- 0%
Gummos citrate	+ 96%	+ 100%	d 46%	- 1%	- 8%	- 8%
Nutrient Agar	+ 100%	+ 100%	+ 100%	+ 100%	+ 100%	- 0%
Oxidase	+ 100%	+ 100%	d 32%	+ 100%	+ 100%	+ 100%
Litmus Milk	K 89%	K 84%	Pop 96%	V	Pep, Red 61%	Pep, Red 50%
Catalase	+ 100%	+ 100%	+ 98%	+ 98%	+ 100%	+ 100%
Pseudosol	d 17%	+ 100%	- 6%	- 0%	- 4%	- 0%
Aesculin	- 0%	- 0%	d 39%	- 5%	- 0%	- 0%
H2S Butt/Paper	- 0/36%	- 0/100%	- 0/95%	- 0/34%	+ 96/100%	+ 100/100%
Tomato Juice	+ 84%	+ 100%	+ 98%	+ 100%	d 16%	+ 100%
Growth at 25/35/42°C	+ 100/100%	+ 100/100%	+ 100/100%	+ 100/100%	+ 100/100%	+ 100/100%
Lysine Lecarbox.	- 0%	- 0%	+ 94%	- 0%	- 0%	- 0%
Ornithine Decarbox.	- 0%	- 0%	- 0%	- 0%	+ 100%	+ 100%
Arginine Dihydro.	d 68%	+ 100%	- 0%	- 0%	- 0%	- 0%
Tyrosine Agar	- 17/0%	- 14/0%	Brown	Tan	Brown(-)	Brown(-)
Acetamide/Tartrate	d/-	d/-	- 0/0%	- 0/0%	- 0/0%	- 0/0%
Acetate/Flucate	+ 100/50%	+ 100/85%	+ 100/0%	+ 100/0%	d/-	+ 100/0%
DNase	- 3%	- 0%	+ 97%	- 0%	+ 100%	+ 100%
Pseudomonas Agar	d 22%	- 0%	d 75%	- 0%	d	d

*Requires minimum of 0.5% NaCl for growth

Figure 2. This Centers for Disease Control (CDC) chart is used for manual identification of bacteria.

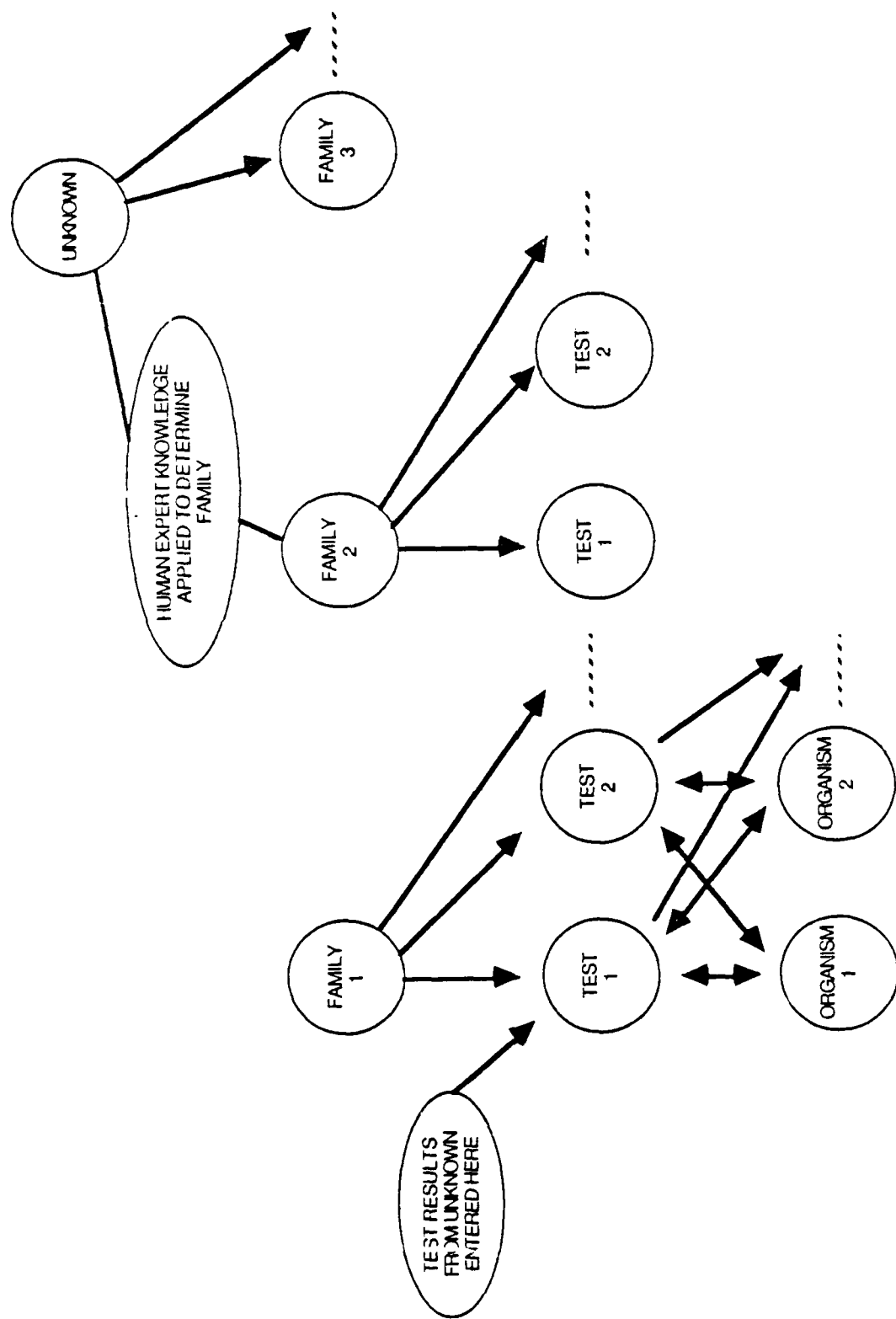


Figure 3. The expert system is a classification system in which knowledge about the unknown is forward chained to the goal state. The goal state is a particular known organism which most closely matches the knowledge about the unknown organism.

MENU FOR GROUP SELECTION

- 1 Enteric
 - 2 Vibrionaceae
 - 3 Gram neg capneic rods
 - 4 Non ferm gram neg
 - 5 Hemophilus
 - 6 Fastidious gram neg
 - 7 Gram pos cocci
 - 8 Gram pos rods (non-sporeformers)
 - 9 Gram neg cocci
 - 10 Anaerobic
 - 11 Staphylococcus
 - 12 Listeria - Erysipelothrix
 - 13 Lactobacillus
 - 14 Large gram pos rods (sporeformer)
 - 15 Unusual gram neg rods
- Please enter group number:

Figure 4. After evaluating the organism's cultural characteristics, the technician selects one or more specific protocols (lists) from the program menu.

EKLM TEST RESULTS

1 OXIDATIVE	N	2 FERMENTATIVE	P	3 LACTOSE	N
4 DEXTROSE	P	5 SUCROSE	N	6 MALTOSE	P
7 MANNITOL	N	8 XYLOSE	N	9 GLYCEROL	P
10 FRUCTOSE	P	11 UREA	N	12 MOTILITY	N
13 GELATIN	P	14 INDOL	N	15 NITRATE	P
16 S. CITRATE	N	17 NUTRIENT AGAR	P	18 BROTH+6% NaCl	P
19 OXIDASE	N	20 LITMUS MILK	P	21 CATALASE	P
22 AESCULIN	N	23 H2S, PAPER	P	24 GROWTH, 25 C	P
25 GROWTH, 35 C	P	26 GROWTH, 42 C	N	27 DNASE	P
28 PIGMENT	N	29 TINSDALE, HALO	P	30 TOXIGENIC	N
31 VP	N				

DECISION: CORYNEBACTERIUM DIPHTHERIAE MITIS 0.9241
C. DIPHTHERIAE GRAVIS 0.8831
C. DIPHTHERIAE INTERMEDIUS 0.8821

FOR CORYNEBACTERIUM DIPHTHERIAE MITIS CHECK TOXIGENIC, HALO, AND UREA
WARNING! CORYNEBACTERIUM DIPHTHERIAE MITIS IS EXTREMELY SERIOUS!
FOR C. DIPHTHERIAE GRAVIS CHECK TOXIGENIC, HALO, AND UREA
WARNING! C. DIPHTHERIAE GRAVIS IS EXTREMELY SERIOUS!
FOR C. DIPHTHERIAE INTERMEDIUS CHECK TOXIGENIC, HALO, AND UREA
WARNING! C. DIPHTHERIAE INTERMEDIUS IS EXTREMELY SERIOUS!

Figure 5. After the technician enters the EKLM Test Results data, the screen displays the biochemical reactions, the three most probable organisms in probability order, and appropriate warnings.

EKLM TEST RESULTS

1 LACTOSE	N	2 DEXTROSE	P	3 DEXTROSE GAS	N
4 SUCROSE	N	5 MALTOSE	P	6 MANNITOL	P
7 XYLOSE	P	8 GLYCEROL	N	9 MALONATE	N
10 UREA	N	11 MOTILITY	P	12 GELATIN (25 C)	N
13 INDOL	N	14 VP	N	15 S. CITRATE	N
16 AESUCLIN HYD	N	17 H2S (KIA)	P	18 LYSINE	P
19 ORNITHINE	N	20 ARGININE	N	21 ACETATE	N
22 RHAMNOSE	N	23 ARABINOSE	N	24 DULCITOL	N
25 INOSITOL	N	26 ADONITOL	N	27 SALICIN	N
28 TREHALOSE	P	29 SORBITOL	P	30 RAFFINOSE	N
31 ONPG	N	32 J. TARTRATE	P	33 PHENYLALANINE	N
34 KCN	N	35 DNA (25 C)	N	36 YEL PIG (25 C)	N
37 MELIBIOSE	P	38 CELLULOSE	N	39 ARABITOL	N
40 METHYL RED	P	41 SEROTYPE	I		

DECISION: S. TYPHI 0.9860
S. GALLINARUM 0.8538
S. CHOLERAESUIS 0.8508

S. GALLINARUM VIOLATES MOTILITY NEGATIVE

WOULD YOU LIKE TO CHECK OTHER TESTS AGAINST THE CANDIDATES? Y

WHAT PERCENT LEVEL DO YOU WANT TO CHECK THE CANDIDATES? 100

ENTER THE NUMBER OF CANDIDATES TO BE CHECKED (1, 2, OR 3): 2
UNKNOWN SHOWS POSITIVE FOR MOTILITY BUT CURRENT DATA SHOWS THAT
S. GALLINARUM ONLY HAS A 0.0% CHANCE OF TESTING POSITIVE

UNKNOWN SHOWS POSITIVE FOR MELIBIOSE BUT CURRENT DATA SHOWS THAT
S. GALLINARUM ONLY HAS A 0.0% CHANCE OF TESTING POSITIVE

DO YOU WISH TO ENTER ANOTHER UNKNOWN (Y/N)?

Figure 6. After the technician enters the EKLM Test Results data, the screen displays the same type of data as Figure 5, but instead of a Warnings field, prompts the technician to continue.

APPENDIX

BIOCHEMICAL TESTS

TESTS LIST #1

- 1 Lactose
- 2 Dextrose
- 3 Dextrose gas
- 4 Sucrose
- 5 Maltose
- 6 Mannitol
- 7 Xylose
- 8 Glycerol
- 9 Malonate
- 10 Urea
- 11 Motility
- 12 Gelatin (25°C)
- 13 Indol
- 14 VP
- 15 S. Citrate
- 16 Aesucilin Hyd.
- 17 H₂S (KIA)
- 18 Lysine
- 19 Ornithine
- 20 Arginine
- 21 Acetate
- 22 Rhamnose
- 23 Arabinose
- 24 Dulcitol
- 25 Inositol
- 26 Adonitol
- 27 Salicin
- 28 Trehalose
- 29 Sorbitol
- 30 Raffinose
- 31 ONPG
- 32 J. Tartrate
- 33 Phenylalanine
- 34 KCN
- 35 DNA (25°C)
- 36 Yel Pig (25°C)
- 37 Melibiose
- 38 Cellobiose
- 39 Arabitol
- 40 Methyl Red
- 41 Serotype

TESTS LIST #2

- 1 Fermentative
- 2 Oxidase
- 3 Dextrose Gas
- 4 Lactose
- 5 Dextrose
- 6 Sucrose
- 7 Maltose
- 8 Mannitol
- 9 Xylose
- 10 Glycerol
- 11 Rhamnose
- 12 Arabinose
- 13 Cellobiose
- 14 Salicin
- 15 Trehalose
- 16 Arabitol
- 17 Urea
- 18 Motility
- 19 Gelatin
- 20 Indol
- 21 Nitrate
- 22 Vp
- 23 S. Citrate
- 24 Catalase
- 25 Esculin
- 26 H₂S(KIA)
- 27 KCN
- 28 Lysine
- 29 Ornithine
- 30 Arginine
- 31 Tyrosine
- 32 J. Tartrate
- 33 Acetate
- 34 Mucate
- 35 D'Nase
- 36 Phenylalanine
- 37 ONPG
- 38 Lipase
- 39 6% NaCl, growth
- 40 10% NaCl, growth

TESTS LIST #3

- 1 Oxidative
- 2 Fermentative
- 3 Dextrose Gas
- 4 MacConkey
- 5 Lactose
- 6 Dextrose
- 7 Sucrose
- 8 Maltose
- 9 Mannitol
- 10 Xylose
- 11 Glycerol
- 12 Fructose
- 13 Urea
- 14 Motility
- 15 Gelatin
- 16 Indol
- 17 Nitrate
- 18 VP
- 19 S. Citrate
- 20 Nut. Agar
- 21 Oxidase
- 22 Litmus Milk
- 23 Catalase
- 24 Esculin
- 25 H₂S Paper
- 26 Growth (25°C)
- 27 Growth (35°C)
- 28 Growth (42°C)
- 29 Lysine
- 30 Ornithine
- 31 Arginine
- 32 Acetamide
- 33 Tartrate
- 34 Acetate
- 35 Mucate
- 36 D'Nase
- 37 Pseudo agar
- 38 Requires CO₂
- 39 Res. to Cephalothrin
- 40 Res. to Nalidixic Acid

TESTS LIST #4

- 1 MacConkey
- 2 SS
- 3 Dextrose
- 4 Lactose
- 5 Sucrose
- 6 Maltose
- 7 Mannitol
- 8 Xylose
- 9 Glycerol
- 10 Fructose
- 11 Urea
- 12 Motility
- 13 Gelatin
- 14 Indol
- 15 Nitrate
- 16 Gas from NO₃
- 17 Nitrite
- 18 S. Citrate
- 19 Nut. agar
- 20 Oxidase
- 21 Catalase
- 22 Litmus milk
- 23 Pseudosel
- 24 Esculin
- 25 H₂S, Butt
- 26 H₂S, paper
- 27 Growth, (25°C)
- 28 Growth, (35°C)
- 29 Growth, (42°C)
- 30 Lysine
- 31 Arginine
- 32 Ornithine
- 33 Tyrosine
- 34 Acetamide
- 35 Tartrate
- 36 Acetate
- 37 Mucate
- 38 D'Nase
- 39 Pseudo agar
- 40 Pigment
- 41 VP

TESTS LIST #5

- 1 Ala (porphyrin test)
- 2 V factor
- 3 Indol
- 4 Urea
- 5 Ornithine
- 6 hemolysis
- 7 Catalase
- 8 Oxidase
- 9 Lactose
- 10 Dextrose
- 11 Sucrose
- 12 Mannitol
- 13 Xylose
- 14 Trehalose
- 15 Nitrate
- 16 CO₂ enhanced growth
- 17 Serotype
- 18 Beta lactamase

TESTS LIST #6

- 1 Fermentative
- 2 MacConkey
- 3 Lactose
- 4 Dextrose
- 5 Sucrose
- 6 Maltose
- 7 Mannitol
- 8 Xylose
- 9 Glycerol
- 10 Fructose
- 11 Esculin
- 12 Urea
- 13 Motility
- 14 Gelatin
- 15 Indol
- 16 Nitrate
- 17 VP
- 18 S. Citrate
- 19 Nut. agar
- 20 Oxidase
- 21 Litmus milk
- 22 Catalase
- 23 Pseudosel
- 24 H₂S Paper
- 25 Growth (25°C)
- 26 Growth (35°C)
- 27 Growth (42°C)
- 28 Lysine
- 29 Ornithine
- 30 Arginine
- 31 Acetamide
- 32 J. Tartrate
- 33 Acetate
- 34 Mucate
- 35 D'Nase

TESTS LIST #7

- 1 VP
- 2 Hippurate
- 3 Esculin
- 4 Pyrrolidonyl-
arylamidase
- 5 Alpha-Galactoridase
- 6 Bet-Glucoronidase
- 7 Beta-Galactosidase
- 8 Alkaline phosphatase
- 9 Leucine Arylamidase
- 10 Arginine
- 11 Ribase
- 12 Arabinose
- 13 Mannitol
- 14 Sorbitol
- 15 Lactose
- 16 Trehalose
- 17 Unulin
- 18 Raffinose
- 19 Starch
- 20 Glycogen
- 21 Beta hemolysis
- 22 Dextran
- 23 Levan

TESTS LIST #8

- 1 Oxidative
- 2 Fermentative
- 3 Lactose
- 4 Dextrose
- 5 Sucrose
- 6 Maltose
- 7 Mannitol
- 8 Xylose
- 9 Glycerol
- 10 Fructose
- 11 Urea
- 12 Motility
- 13 Gelatin
- 14 Indol
- 15 Nitrate
- 16 S. Citrate
- 17 Nutrient Agar
- 18 Broth +6% NaCl
- 19 Oxidase
- 20 Litmus milk
- 21 Catalase
- 22 Aesculin
- 23 H₂S, paper
- 24 Growth, 25°C
- 25 Growth, 35°C
- 26 Growth, 42°C
- 27 D'Nase
- 28 Pigment
- 29 Tinsdale, halo
- 30 Toxigenic
- 31 VP

TESTS LIST #9

- 1 Oxidative
- 2 Fermentative
- 3 Dextrose, Gas
- 4 MacConkey
- 5 Lactose
- 6 Dextrose
- 7 Sucrose
- 8 Maltose
- 9 Mannitol
- 10 Xylose
- 11 Glycerol
- 12 Fructose
- 13 Urea
- 14 Gelatin
- 15 Indol
- 16 Nitrate
- 17 Nitrite
- 18 VP
- 19 S. Citrate
- 20 Nutrient Agar
- 21 Oxidase
- 22 Litmus milk
- 23 Catalase
- 24 Acetate
- 25 H₂S, Paper
- 26 Growth, 25°C
- 27 Growth, 35°C
- 28 Growth, 42°C
- 29 Tyrosine
- 30 Tartrate
- 31 Mucate
- 32 D'Nase
- 33 Amylosucrase
- 34 Phenylalanine
- 35 ONPG
- 36 Serotype

TESTS LIST #10

- 1 Indol
- 2 p-nitrophenyl-N
-acetyl-B-D-
glucosaminide
- 3 p-nitrophenyl- α -D
glucoside
- 4 p-nitrophenyl- α -L
arabinofuranoside
- 5 p-nitrophenyl-B-D
glucoside
- 6 p-nitrophenyl- α -
fucoside
- 7 p-nitrophenyl-
phosphate
- 8 p-nitrophenyl- α -D-
galactoside
- 9 O-nitrophenyl B-D
galactoside
- 10 Indoxyl-acetate
- 11 Arginine
- 12 L-Leucyl-4-methoxy-
B-naphthylamide
- 13 L-proline-B
naphthylamide
- 14 L-pyrrolidonyl-B-
naphthylamide
- 15 L-Tyrosine-B-
naphthylamide
- 16 L-arginine-B-
naphthylamine
- 17 L-alanyl-L-alanyl-B
naphthylamide
- 18 L-histidine-B-
naphthylamide
- 19 L-phenylalanine-B-
naphthylamide
- 20 L-Glycine-B-
naphthylamide
- 21 Catalase

TESTS LIST #11

- 1 Colony, large
- 2 Pigment
- 3 Anaerobic
- 4 Aerobic
- 5 Coag.
- 6 Hemolysis
- 7 Nitrate
- 8 VP
- 9 Phosphate
- 10 Urease
- 11 Arg
- 12 Beta-Glucosidase
- 13 Beta-Glucoronide
- 14 Beta-Galactosidase
- 15 Novobiocin Res.
- 16 Trehalose
- 17 Mannitol
- 18 Xylose
- 19 Cellobiose
- 20 Sucrose
- 21 Mannose
- 22 Ribose
- 23 Raffinose
- 24 Lactose

TESTS LIST #12

- 1 Fermentative
- 2 Lactose
- 3 Dextrose
- 4 Sucrose
- 5 Maltose
- 6 Mannitol
- 7 Xylose
- 8 Glycerol
- 9 Fructose
- 10 Rhamnose
- 11 Urea
- 12 Motility
- 13 Gelatin
- 14 Indol
- 15 Nitrate
- 16 Nitrite
- 17 VP
- 18 S. Citrate
- 19 Nut. Agar
- 20 Broth + 6.5 NaCl
- 21 Oxidase
- 22 Litmus milk
- 23 Catalase
- 24 S. aureus Camp
- 25 Aesculin
- 26 H₂S Butt
- 27 H₂S paper
- 28 Growth 25°C
- 29 Growth 35°C
- 30 Growth 42°C
- 31 D'Nase
- 32 Beta hemolysis

TESTS LIST #13

- 1 Alpha hemolysis
- 2 Gas, Dextrose, Thio
- 3 Anaerobic growth
- 4 Lactose
- 5 Dextrose
- 6 Sucrose
- 7 Maltose
- 8 Mannitol
- 9 Xylose
- 10 Fructose
- 11 Rhamnose
- 12 Arabinose
- 13 Salicin
- 14 Urea
- 15 Motility
- 16 Indol
- 17 Nitrate
- 18 S. Citrate
- 19 Nut. Agar
- 20 Oxidase
- 21 Litmus milk, acid
- 22 Catalase
- 23 Aesculin
- 24 KIA, A, slant
- 25 H₂S Paper
- 26 Growth 25°C
- 27 Growth 35°C
- 28 Growth 42°C
- 29 Prefer CO₂

TESTS LIST # 14

- 1 Oxidative
- 2 Fermentative
- 3 Gas, Dextrose
- 4 Lactose
- 5 Dextrose
- 6 Sucrose
- 7 Maltose
- 8 Mannitol
- 9 Xylose
- 10 Glycerol
- 11 Fructose
- 12 Salicin
- 13 Urea
- 14 Motility
- 15 Gelatin
- 16 Indol
- 17 Nitrate
- 18 VP
- 19 S. Citrate
- 20 Nut. Broth
- 21 Nut. Broth +6% NaCl
- 22 Oxidase
- 23 Litmus Milk
- 24 Catalase
- 25 Aesculin
- 26 KIA, But, acid
- 27 KIAQ, Slant acid
- 28 H₂S, Butt
- 29 H₂S, Paper
- 30 Growth, 25°C
- 31 Growth, 35°C
- 32 Growth, 42°C
- 33 Lysine
- 34 Ornithine
- 35 Arginine
- 36 D'Nase
- 37 Acetamide
- 38 Tartrate
- 39 Acetate
- 40 Mucate
- 41 Starch
- 42 Lecithinase
- 43 Meth. Blue Red
- 44 Hemolysis

TESTS LIST #15

- 1 Fermentative
- 2 Gas, Dextrose
- 3 MacConkey
- 4 SS
- 5 Lactose
- 6 Dextrose
- 7 Sucrose
- 8 Maltose
- 9 Mannitol
- 10 Xylose
- 11 Glycerol
- 12 Fructose
- 13 Urea
- 14 Motility
- 15 Gelatin
- 16 Indol
- 17 Nitrate
- 18 Nitrite
- 19 VP
- 20 S. Citrate
- 21 Nut. Agar
- 22 Oxidase
- 23 Litmus Milk
- 24 Catalase
- 25 Pseudosel
- 26 Aesculin
- 27 KIA, Butt, acid
- 28 KIA, Slant, acid
- 29 H₂S, Butt
- 30 H₂S, Paper
- 31 Growth 25°C
- 32 Growth 35°C
- 33 Growth 42°C
- 34 Lysine
- 35 Ornithine
- 36 Arginine
- 37 Tyrosine
- 38 Acetamide
- 39 Tartrate
- 40 Acetate
- 41 Mucate
- 42 D'Nase
- 43 Amylosucrose
- 44 Hemolysis
- 45 Pigment